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## Appendix C

# CSO Control Program Review Detail

<b>Maximizing Use of Existing CSO Control Facilities.....</b>	<b>C-2</b>
Inventory of CSO Control Roles and Responsibilities.....	C-2
Workshop and Staff Survey .....	C-4
<b>Identifying the Public and Environmental Health Benefits.....</b>	<b>C-5</b>
CSO Water Quality Assessment—King County, 1998.....	C-5
Studies in Response to Endangered Species Act Listings—Various Entities, 1999–2005 .....	C-6
Sediment Management Activities—King County WTD and Others, 1999–2005.....	C-16
Climate Change and Sea Level Rise .....	C-20
<b>Analyzing Rate Impacts .....</b>	<b>C-22</b>
Updated RWSP Cost Estimates .....	C-22
Cost Control—CSO Treatment Technology Review .....	C-23
<b>Assessing Public Opinion—CSO WQA Stakeholder Committee.....</b>	<b>C-26</b>

## Maximizing Use of Existing CSO Control Facilities

The review assumed that cost-effective use of facilities resulted not just from good operation and maintenance of physical structures and optimized control strategies, but also efficient coordination and communication between the employees carrying out those activities. The review included physically inspecting each CSO facility and rain gauge to supplement ongoing inspection programs, reviewing monitoring data, and making improvements based on the inspections and review. The scope was then broadened to include topics such as control program organization, coordination, and communication as means to effective program implementation. A workshop and follow-up meetings were held across the division not only to identify ways to maximize the use of existing facilities but also to improve the coordination framework and methodologies that implement the program. An outcome of these meetings was a survey of staff to identify their communication needs and various approaches to meet these needs. Key survey recommendations are being implemented.

## Inventory of CSO Control Roles and Responsibilities

The first step of this part of the review was to inventory roles and responsibilities within WTD that relate to these tasks. Almost every group in WTD is involved in the program to some extent, including wastewater treatment plant operators and planning, capital improvement, and asset management staff. Groups with diverse responsibilities and in diverse locations must coordinate their activities. An additional challenge to coordination is the division of the operation, maintenance, and offsite groups into two sections—West and East—that roughly correspond to where flows are sent, either to West Point or South plant.<sup>1</sup> The groups and their responsibilities as they relate to CSO control are presented in the following sections.

### Operation, Maintenance, and Offsite Staff

#### West Section staff:

- Use SCADA to maximize the movement of flow to the West Point plant for secondary treatment and to use all available capacity in the system through in-line storage.
- Maintain dry-weather wet well level at the largest pump station when a storm is approaching. This enables the collection system to convey more flow to West Point before the storm or during the initial part of a storm and to free more storage or conveyance capacity for the storm flows.
- Operate the Carkeek and Mercer/Elliott West CSO treatment facilities.

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<sup>1</sup> “Offsite” refers to facilities such as pump stations that are not part of a treatment plant site.

**East Section staff:**

- Manage combined sewer system flows from the southeast part of the Seattle area via the Allentown Diversion.
- Operate the Alki and Henderson/Norfolk CSO treatment facilities and the Alki conveyance system.

**Both West and East Section staff:**

- Operate and conduct normal maintenance programs to ensure reliable operation of pump and regulator stations.
- Plan for wet season operation of the CSO treatment plants and facilities.
- Coordinate seasonal flow-swaps at the York Pump Station, diverting flows to the South plant to relieve the west side combined sewer system in the winter.

**Planning Staff**

In general, planning staff are responsible for modeling, flow monitoring, program management, permitting, and industrial waste:

- **Modeling.** Estimates current and future conditions to assess control progress, supports upgrades to the CATAD/SCADA system, recommends system set points to optimize system operation, and provides targets for new facility design.
- **Flow Monitoring.** Directs the placement of portable monitors; downloads and assesses flow data used for compliance reporting, progress measurement, and facility design.
- **Program Management.** Coordinates plan implementation, annual reports, plan updates, and regulatory/policy review.
- **Permitting.** Coordinates NPDES permit compliance, provides liaison with the Washington State Department of Ecology (Ecology), and provides regulatory interpretation and planning.
- **Industrial Waste.** Permits discharges into the system, sets standards for pollution prevention and volume control, and conducts source control efforts in separated basins and upstream of sediment remediation sites.

**Asset Management Staff**

- **Inspection staff.** Place and manage portable monitors, inspect offsite facilities such as pipelines, siphons, and outfalls, and conduct normal maintenance programs to ensure the integrity and reliable operation of the offsite facilities.
- **Engineering Staff.** Provide interagency project coordination and implement any needed system refurbishment or upgrade projects.

## Major Capital Improvement Program Staff

- Coordinate predesign through construction of major facilities.
- Manage contracts.

## Workshop and Staff Survey

A workshop was held on November 16, 2004. The purpose of the workshop was to identify ways to improve the use of existing CSO facilities, including ways to improve coordination and communication among the employees supporting the program. In January and February 2005, two follow-up meetings were held with treatment plant and engineering staff to review the workshop findings.

Workshop participants proposed a vision statement for a well-coordinated CSO control program and goals to support the vision statement. The vision statement and goals will continue to be discussed and refined to ensure that they represent an agreed-on agency approach. Participants also discussed past experiences to help them identify coordination hurdles and ways to overcome them. Some of the resulting suggestions are as follows:

- **Communication**—Develop more formal communication channels for CSO information across the various WTD Workgroups.
- **Staffing**—Identify or confirm a central figure with authority to address staff needs and CSO work activities across the various WTD workgroups.
- **Data**—Provide up-to-date information systems with simpler data access or transfer capabilities.
- **Guidelines**—Develop CSO control optimization guidelines that better integrate CSO within the overall WTD.
- **Regulatory**—Continue to involve the regulatory agencies in initial planning, and educate WTD staff on regulatory requirements for CSO.
- **Incentive**—Encourage innovation and ideas for improvement; reward ideas that are implemented.
- **Financial**—Prioritize the allocation of resources among operations, maintenance, and capital improvements groups throughout WTD through uniform cost-benefit analyses, and identify a budget for completing optimization activities.

## Identifying the Public and Environmental Health Benefits

For this CSO control program review, WTD took a fresh look at existing information, reviewed new information, and completed studies to assess—both quantitatively and qualitatively—the health benefits to the public, environment, and endangered species of completing the program. The assessment drew from studies describing existing environmental conditions and predicted conditions at the completion of the program. It built on the findings of the County’s 1998 *Water Quality Assessment of the Duwamish River and Elliott Bay* (WQA) and 1999 Sediment Management Plan—both done in support of the Regional Wastewater Services Plan (RWSP)—and on subsequent annual water quality reports. A summary of the information considered in this review follows.

### CSO Water Quality Assessment—King County, 1998

The 1998 *Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay* (WQA) reviewed the health of the Duwamish River and Elliott Bay estuary and the effects of CSO discharges. A computer model was developed to predict existing and future water and sediment quality conditions, and a risk assessment was undertaken to identify risks to aquatic life, wildlife, and human health. Findings identified during the course the WQA were taken into account during development of the RWSP CSO control program.

The WQA found some risks to fish, wildlife, and humans from conditions in the estuary as it existed at the time, but predicted limited improvement if CSO discharges were eliminated from the estuary (Table 1).

The findings of the WQA helped determine the priority of the CSO projects in the RWSP. It was recommended that locations with the greater potential for human contact—the Puget Sound beaches—be controlled first. Locations in the Duwamish River were set later in the schedule on the basis of what was understood at the time to be a lower human health and environmental benefit from CSO control at these sites.

#### Some Chemicals Defined...

**PCBs** (polychlorinated biphenyls). Used in electrical equipment, paints, plastics, dyes, and other products, before being banned in the U.S in 1977. Known to cause cancer in animals and produce health effects in humans.

**PAHs** (polycyclic aromatic hydrocarbons). Byproducts of combustion of coal, oil, gas, wood, garbage, and tobacco, and in charboiled meat. May cause cancer, reproductive problems, birth defects, impaired immune function, and other health effects.

**EDCs** (endocrine disrupting chemicals). May be in natural or synthetic hormones, personal care products, industrial byproducts, plastics, and pesticides. Mimic, inhibit, or alter the hormonal regulation of the immune, reproductive, or nervous systems or other parts of the endocrine system.

**TBT** (tributyl tin). An EDC used in paints and as a pesticide. Is stable, persists in the environment, and is toxic to aquatic life.

**Phthalates**. Used in a variety of consumer products such as deodorant, nail polish, and perfume. Found to cause adverse health effects, including cancer, in laboratory animals.

**Furans** (and related dioxins). Byproducts of combustion, manufacture of herbicides, and bleaching of paper pulp. Found to cause adverse effects, including endocrine disruption, in laboratory animals. May cause cancer in humans.

**Table 1. Water Quality Assessment Findings Regarding CSOs**

<b>Risk Target</b>	<b>Risk</b>	<b>CSO Control Benefit</b>
Water column—dwelling aquatic organisms; salmon by direct or dietary exposure	None identified	No benefit
Sediment-dwelling organisms; salmon via dietary exposure	Potential risk from PCBs, TBT, bis(2-ethylhexyl) phthalate, mercury, PAHs; low risk from 1,4-dichlorobenzene	Slightly reduced risk <sup>a</sup> ; slight decrease in loadings of bis(2-ethylhexyl) phthalate, mercury, PAHs, and 1,4-dichlorobenzene
Wildlife	Low-to-high risks, depending on the species, from PCBs, lead, copper, and zinc	Slight decrease in loadings of lead, copper, and zinc
Humans – chemical exposures	Significant risk from exposure to arsenic and PCBs from fish consumption; potential risk from exposure to arsenic and PCBs when netfishing, swimming, windsurfing, and SCUBA diving	No benefit; the identified risk is not related to CSOs
Humans – pathogen exposures	Potential risk from fecal coliform, giardia, and viruses. People should avoid water contact during and for 48 hours after overflows.	Reduced risk; any benefit from reduced fecal coliform would not be apparent because inputs from other sources are so high

<sup>a</sup> CSOs were not believed to be a significant source of PCBs or tributyl tin (TBT), but were considered a moderate source of 1,4 –dichlorobenzene.

## Studies in Response to Endangered Species Act Listings—Various Entities, 1999–2005

In 1999, just before King County adopted the RWSP, the federal government listed Puget Sound Chinook salmon and bull trout as threatened under the Endangered Species Act. Just recently in 2006, killer whales were listed as endangered species.

Chinook salmon, also known as king salmon or blackmouth salmon, belong to the family Salmonidae and are one of eight species of Pacific salmonids in the genus *Oncorhynchus*. Chinook salmon are anadromous. That is, adults migrate from a marine environment into the freshwater streams and rivers of their birth to spawn (only once) and then die. Juvenile salmon feed and migrate in the shallow areas of rivers, streams, lakes, estuaries, and nearshore areas. They eventually migrate to the ocean, where, as adults, they will spend 3 to 4 years on average. Juveniles are present at different times in different water bodies, depending on life stage. Adult Chinook use the deep areas of the marine water bodies for foraging and the estuarine and freshwater areas for migration back to their spawning grounds.

Bull trout are members of the char subgroup of the salmon family. Some bull trout populations are migratory, spending portions of their lifecycle in larger rivers or lakes before returning to smaller streams to spawn. Others complete their entire lifecycle in the same stream. Some bull trout in the Coastal-Puget Sound population migrate between fresh water and the marine environment. Given the varied life history strategies of bull trout and the limited information

regarding the species (WDFW, 1998), the U.S. Fish and Wildlife Service (USFWS) assumes the presence of bull trout everywhere in their historical range unless proven otherwise. Bull trout are likely to occur in the same water bodies, except for Lake Washington, as outmigrating juvenile Chinook (which they prey on).

The decline of Chinook and other salmonid species has generally been attributed to four factors: habitat, hydropower, harvest, and hatcheries. Of the four factors, improvement of habitat quality would be the factor most closely linked with CSO. At the time of the listings, knowledge of the habitat needs, foraging areas, residence time, and other critical life stages of bull trout and Puget Sound Chinook was limited. Since the time of the listings, numerous organizations, both public and private, have worked to raise the collective level of knowledge and assess the needs of salmon. WTD has worked with the U.S. Army Corp of Engineers, USFWS, the City of Seattle, NOAA Fisheries, the tribes, and the Washington State Department of Fish and Wildlife (DFW) to increase our knowledge about Chinook and bull trout.

King County and City of Seattle CSO discharge points exist in the lower reaches of each of the two primary watersheds, called Water Resource Inventory Areas (WRIAs), in King County's wastewater service area: the Lake Washington/Cedar/Sammamish watershed (WRIA 8) and the Green/Duwamish and Central Puget Sound watershed (WRIA 9). Many of the questions that need to be answered for WRIA planning are identical to those that WTD must address in various projects, including CSO control. While the scientific needs of WRIA planning have been greater (for instance, in terms of geographic extent) than the specific needs of WTD, the success of WRIA planning will ensure a sound framework for the development of reasonable federal ESA requirements for the RWSP. Current watershed planning in response to the Chinook listing as threatened will support conservation of multiple species, including bull trout. King County supports the WRIA planning efforts that are addressing ESA issues within the County. Additional information about the WRIA planning efforts can be found in the King County *RWSP Annual Water Quality Report* and WRIA-related publications.

## **Presence of Threatened Salmon in King County Watersheds**

The following sections describe the general characteristics of WRIAs 8 and 9, and present available information on the presence, abundance, and duration of threatened species within each watershed. Figure 1 shows the locations of the watersheds.

### **WRIA 8**

The Lake Washington/Cedar/Sammamish watershed covers 692 square miles and contains two major river systems (Cedar and Sammamish), three large lakes (Washington, Sammamish, and Union), and numerous creeks including Issaquah and Bear Creeks. The basin drains into Puget Sound through the Ship Canal and Hiram Chittenden (Ballard) Locks. The WRIA includes the marine nearshore and a number of smaller creeks that drain directly to Puget Sound between West Point in the City of Seattle northward to Elliott Point in the City of Mukilteo in Snohomish County. WRIA 8 is the most densely populated watershed in Washington State, with approximately 1.3 million people in 2002 and an expected 1.6 million more people by 2022. King County CSOs along Lake Washington are controlled, but uncontrolled CSOs remain along the Ship Canal and nearshore areas near Carkeek Park.

Three Chinook populations inhabit the watershed: the Cedar River population, the North Lake Washington population, and the Issaquah population. The Cedar River population spawns in the Cedar River's main stem and to a lesser extent in its tributaries. When juveniles leave their river in the spring, they rear and migrate in shallow habitats along Lake Washington's shorelines, particularly in the south end. The North Lake Washington population spawns in the tributaries to northern Lake Washington and the Sammamish River, including Bear, Little Bear, North, and Kelsey Creeks. Issaquah Chinook spawn in Laughing Jacobs Creek. Propagation occurs through both natural spawning in the wild, and artificial spawning in the Issaquah hatchery. The three populations migrate in and out of the watershed through the lakes, Ship Canal, and Locks. Juveniles rear in the marine nearshore areas of Puget Sound before heading into the ocean. Assessments indicate that all three populations are at extremely high risk of extinction. The Cedar River population is at highest risk, followed by North Lake Washington and then Issaquah populations.<sup>2</sup>

### **WRIA 9**

WRIA 9 is 568 square miles. Thirty percent of the WRIA is in the Urban Growth Area (UGA). In 1999, the population in WRIA 9 was estimated at 563,980 (adapted from PSRC data, 2000). About 89 percent of the population live in the UGA and 11 percent live in rural areas or resource lands. Two sub-watersheds are directly affected by CSOs: the Duwamish Estuary Sub-watershed and the Nearshore Sub-watershed. The Duwamish Estuary Sub-watershed is predominantly urban residential, commercial, and industrial. Nearly all the Nearshore Sub-watershed is urban residential. King County CSOs are located in the lower Duwamish River from the turning basin to the mouth, in Elliott Bay, and along the Alki shoreline.

The Green/Duwamish River system currently supports an average yearly total run (fish returning to the river and those caught in fisheries) of about 41,000 adult Chinook salmon. The run is divided into hatchery and naturally spawning populations. The naturally spawning component of the Chinook run contains a mixture of wild and stray hatchery Chinook. The percentage of the wild component is unknown. Wild run size has been higher during recent years (1983–1996) compared to earlier years (1968–1982), indicating that the downward trend common to other Puget Sound stocks is not evident among “wild” Green River Chinook salmon. Likewise, the Green River has not experienced the same decline in naturally spawning fish as has occurred in other streams in Puget Sound. The spawning goal has been met 6 of the last 10 years. The persistence of the naturally spawning component of the run is consistent with a high survival rate. Overall, Green River Chinook are resilient and have survived the effects of large-scale production of hatchery fish, high harvest rates, and habitat alteration. The spawning returns have been steady, though somewhat cyclical (Figure 2).<sup>3</sup>

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<sup>2</sup> September 2002. *Salmon and Steelhead Limiting Factors Report for the Cedar Sammamish Basin (Water Resource Inventory Area 8)*.

<sup>3</sup> December 2000, *WRIA 9 Habitat Limiting Factors and Reconnaissance Assessment for Salmon Habitat in the Green/Duwamish and Central Puget Sound Watershed*.

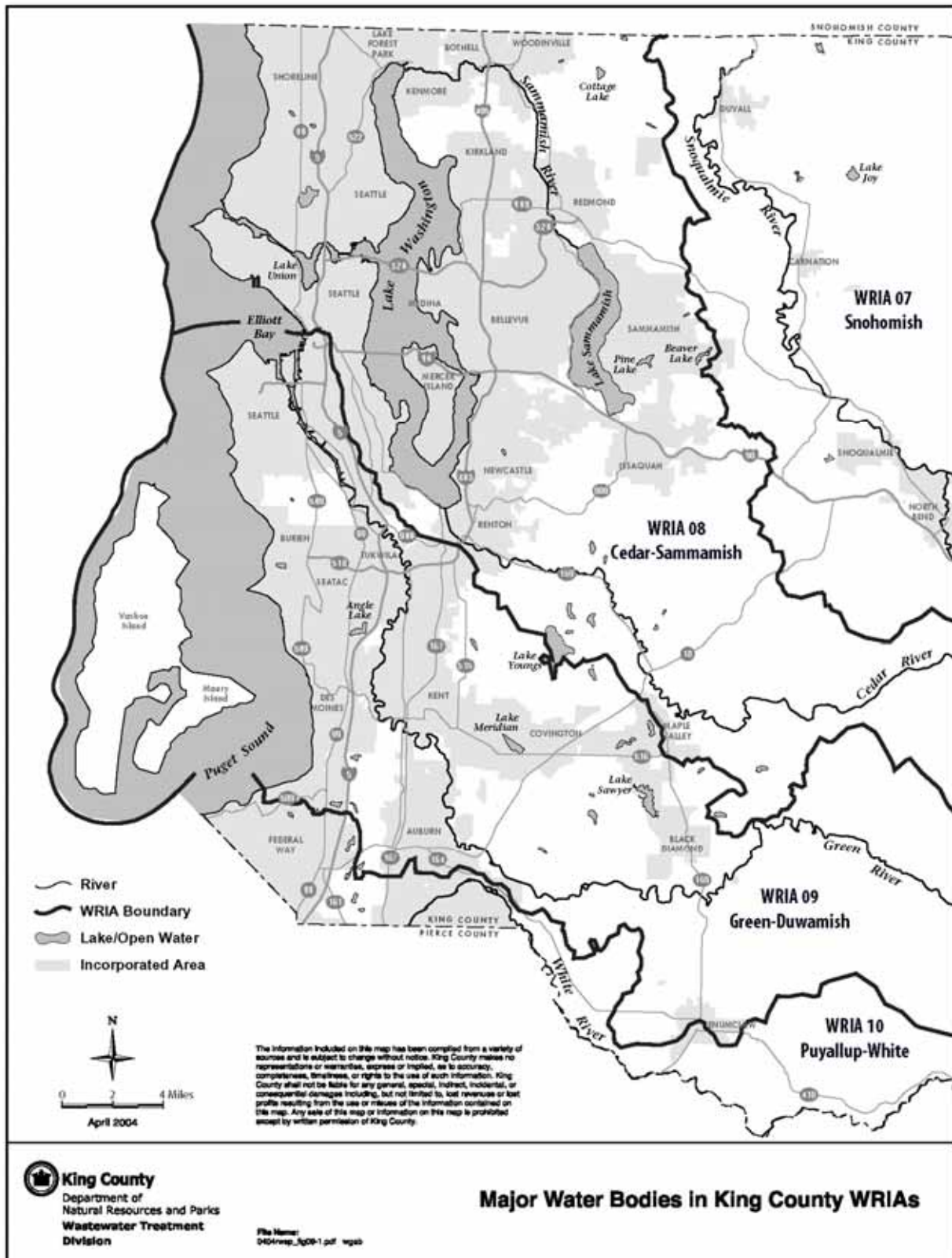
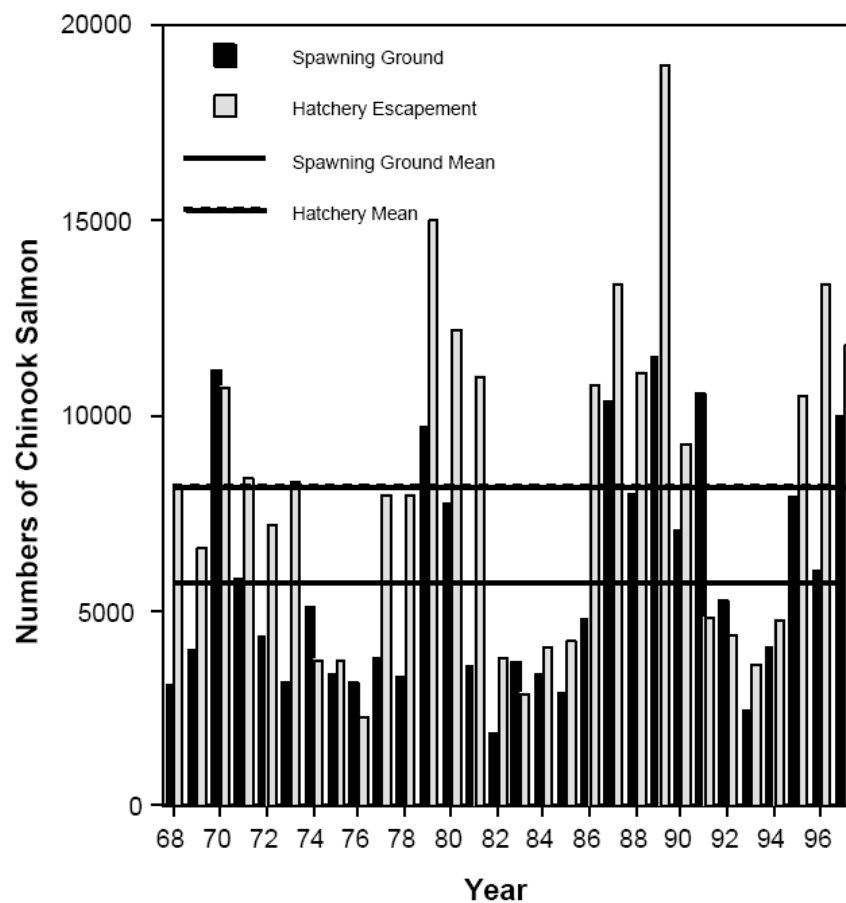


Figure 1. Major Water Bodies in King County WRIs



Time series of chinook salmon returning to the spawning grounds and to the hatcheries, 1968-1997. Spawning ground estimates include an unknown number of stray hatchery salmon. Mean values are shown. Data source: WDFW 1998.

**Figure 2. Time Series of Green River Chinook Salmon Returning to the Spawning Grounds and to the Hatcheries, 1968-1997**

Four different trajectories for juvenile Chinook are defined by the timing and size at which the fish reach the Duwamish estuary. The endpoint of each rearing trajectory is a juvenile that is ready to move offshore from near the river mouth into the greater Puget Sound estuary. The four trajectories are as follows:

- Emergent fry (1.6 to 1.8 inches) are uncommon in the estuary but may be present for months between March to late May, and in the Elliott Bay shoreline for several weeks to months between May and June.
- Fry/fingerlings (1.8 to 2.8 inches) are present in the estuary for several days to months between early April and late May, and in Elliott Bay for several weeks to months between May and June.
- Fingerlings (over 2.8 inches) are abundant in the estuary for several days to two weeks between late April and mid-June, and in Elliott Bay for several days to 2 weeks between May and June.
- Yearlings are uncommon and are seen only briefly in the estuary.

### **Watershed Planning—Various Entities, 2000–2005**

In 2000, watershed planning activities began under precedent-setting interlocal agreements. These agreements involve cost sharing by more than 45 jurisdictions in support of the salmon conservation planning effort and provide for the creation of a new governance-management construct. In 2003 and continuing through 2005, the planning effort turned from assessments to development of Salmon Conservation Plans (also termed Habitat Plans).

Many of the questions that need to be answered for the WRIAs are identical to those that WTD must address in various projects, including CSO control. While the scientific needs of the WRIAs are greater (for instance, in terms of geographic extent) than the specific needs of WTD, the success of WRIA planning will ensure a sound framework for reasonable federal ESA requirements for the RWSP.

Salmon Conservation Plans have now been approved and published by the respective Forums (composed of local elected leaders representing the jurisdictions that have funded the planning effort)—WRIA 8 in July 2005 and WRIA 9 in August 2005. In 2005, the WRIA Forums addressed Salmon Conservation Plan implementation, the governance-management construct that they will develop, and the funding mechanisms necessary to implement the plans. In addition, negotiations with NOAA Fisheries and USFWS are occurring as the WRIA plans are rolled up into a regional recovery plan under the Shared Strategy for Puget Sound.

The Salmon Conservation Plans describe long-term habitat conservation and recovery actions in WRIAs 8 and 9 that take an ecological approach but concentrate on the needs of the ESA-listed species of Chinook salmon and bull trout. They include strategies, policies, and recommended projects to address the factors that limit salmon habitat in the watersheds that were identified earlier in reports published by the Washington Conservation Commission.<sup>4</sup> Most habitat-limiting

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<sup>4</sup> December 2000. *Habitat Limiting Factors and Reconnaissance Assessment Report for the Green/Duwamish and Central Puget Sound Watersheds (Water Resource Inventory Area 9)*.

factors have occurred from development for human uses. The factors are similar for the lakes, rivers, and creeks, although the magnitude of impact varies by type of water body and specific watershed area. Moreover, the factors interact with one another to worsen the habitat problems seen in the aquatic systems. Factors shared by both watersheds include altered hydrology, habitat changes fostering increased predator populations, loss of floodplain connectivity, bulkheads in the marine nearshore that cut off much of the sediment supply to marine habitats, disrupted sediment processes, lack of riparian vegetation, loss of channel and shoreline complexity, barriers to fish passage, water withdrawals, and degraded water and sediment quality.

Both WRIA plans recommend actions in their lower reaches that should be considered in CSO planning. Both advocate that efforts be increased to protect sediment and water quality, especially near commercial and industrial areas where there is the potential for fuel spills, discharge of pollutants, and degraded stormwater quality. Because of the highly diluted nature of CSOs and the high level of uncertainty surrounding the effects of constituents found in CSOs on listed species, it is difficult to quantify any impact on bull trout or Chinook. While not a top concern to the WRIAs, there is the perception that CSO contributes to the degradation of water and sediment quality in salmon habitat. Associated with this perception is a larger concern about impacts from stormwater.

Habitat quality in the transitional areas of the estuaries is a priority. The WRIA 8 plan recommends the creation of pocket estuaries in the Ship Canal near the Locks in order to increase the estuary area transition zone, while the WRIA 9 plan recommends enlargement of the Duwamish estuarine transition zone habitat by expanding the shallow water and slow water areas. The WRIA 9 plan recommends that area projects be leveraged to create improved habitat. It specifically mentions sediment quality improvements through the Lower Duwamish Waterway Superfund cleanup. Other cleanup/control efforts and projects such as the Alaskan Way Viaduct and Seawall Replacement may be approached as opportunities to rehabilitate and create new shallow water beach habitat. Future CSO control projects will also likely be viewed as opportunities.

### **Habitat Conservation Planning—King County Wastewater Treatment Division, 1999–2005**

The listing of bull trout and Chinook salmon as threatened under the ESA also prompted King County WTD to undertake the creation of a Habitat Conservation Plan (HCP) for all its activities that have any potential for “take.” Take under ESA means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct [ESA §3(19)]. Harm is further defined by USFWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering. An HCP is a long-term voluntary agreement that usually contains an adaptive management provision outlining plans for dealing with uncertainties over the life of the agreement.

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September 2002. *Salmon and Steelhead Limiting Factors Report for the Cedar Sammamish Basin (Water Resource Inventory Area 8)*.

### ***HCP Process and Decisions***

The HCP was proposed as a voluntary, two-phased, 40-year agreement with NOAA Fisheries and USFWS (the Services) that outlined WTD's efforts to protect threatened and endangered species, while carrying on its wastewater management activities. Phase I covered operational wastewater discharges from the South and West Point Treatment Plants and construction and maintenance of gravity sewers, force mains, pump stations, and storage facilities. The Brightwater System, which was included in the original HCP scope, was removed to pursue independent permitting for the project. The scope of Phase II included analysis of CSOs. WTD representatives produced several in-depth technical papers and worked toward negotiated agreements that would provide the framework for the HCP.

In April 2005, after completion of Phase I and after meetings with Services managers, the HCP effort was stopped. The WTD activities contained in the Phase I analyses included adequate avoidance and minimization measures, and any potential remaining impacts could not be quantified because of the uncertainty of effects on listed species. Because the uncertainties were so large, the commitment of resources required to match the uncertainty level was substantial. WTD felt that the long-term expense did not justify the uncertain risk and chose to seek individual ESA Section 7 consultations for projects with a federal link.

### ***Results of HCP Studies on Bioaccumulating Chemicals***

While it is relatively simple to identify areas of potential take from construction activities such as land clearing or laying pipe and then to use methods to avoid or minimize impacts, it is more difficult to understand potential sub-lethal effects on salmon from the discharge of treated effluent. Discharges from WTD's secondary treatment plants occur deep in Puget Sound. CSOs occur during periods of heavy rains, resulting in a highly dilute discharge. The potential effects on salmon of constituents contained in these discharges will depend on both length of time of the exposure, bioaccumulation (if any) in prey species, and the relative toxicity and concentration levels of the constituent.<sup>5</sup>

As part of the process to develop an HCP, WTD reviewed available information to assess the potential for King County secondary treatment plant effluent discharges to contribute to any bioaccumulation of persistent bioaccumulative toxins (PBTs) and endocrine disrupting chemicals (EDCs). This information does not directly apply to CSOs because secondary treatment will remove many chemicals that were in the wastewater. However, the study does provide information that was reviewed for any applicability. The risks resulting from CSOs appear to be low because the chemical concentrations in CSOs are low and exposure is brief and infrequent. Studies will continue until definitive answers are known and regulations instituted. Findings are discussed in more detail in the following sections.

### **Persistent Bioaccumulative Toxins**

WTD assessed 33 chemicals that are found in effluent and identified on lists of PBTs developed by state, federal, and international agencies. The 33 PBTs were classified based on whether

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<sup>5</sup> In bioaccumulation, low concentrations of chemicals build up in the food web to levels resulting in tissue concentrations that are harmful to aquatic organisms or to those that prey on them, including humans.

available data suggested they might be bioaccumulating and to whether King County's discharges might be a significant source relative to other sources. Twelve PBTs appear to be bioaccumulating in the Puget Sound food web. These PBTs, grouped by category are as follows: pesticides (alpha/gamma chlordane, DDD, DDE, DDT, and dieldrin); PCBs (total PCBs, Arochlor 1242, Arochlor 1248, Arochlor 1254, and Arochlor 1260); dioxins (PCDDs), and furans (PCDF). Compared to other sources, it does not appear that WTD secondary effluents are significant contributors of these chemicals. Most appear to come from diffuse sources or are no longer being produced, but persist and may move between environmental media, for example from air to stormwater, or from groundwater infiltrating into sewers. Although they have not been detected in CSOs, the chemicals may be present in levels below detection limits.

Mercury also appears to be bioaccumulating in the Puget Sound food web. Mercury has been found in sediment near County outfalls, and in influent, secondary effluent, reclaimed water, biosolids, and CSOs. Not enough data are available to determine if County effluents and CSOs are significant contributors relative to others. In any event, the County has identified common sources of mercury and adopted specific rules to limit mercury discharges by area dentists, the greatest known source of mercury, into its collection system.

Assessment results were published in April 2002 as *Bioaccumulation and King County Secondary Treated Effluent: Data Review, Method Evaluation, and Potential for Impacts on Puget Sound Aquatic Life*.

### **Endocrine-Disrupting Chemicals**

Endocrine glands produce hormones that regulate metabolic processes. Chemicals that are endocrine disruptors mimic, inhibit, or alter this hormonal regulation of systems, such as the immune, reproductive, or nervous system or other parts of the endocrine system. Many potential endocrine disruptors are chemicals common in the environment because people use them in every aspect of their lives. Some endocrine-disrupting chemicals (EDCs) may be in natural or synthetic hormones, personal care products like soaps and cosmetics, industrial byproducts, plastics, and pesticides. This area of study is so new that scientists are still discovering what groups of chemicals are EDCs. Studies will continue for many years before definitive answers are known and regulations instituted.

As part of the HCP process, current scientific literature on endocrine disruptors was reviewed, including their presence in wastewater effluents and their effects on aquatic species.<sup>6</sup> The review concluded that there is inadequate knowledge of which chemicals exert endocrine disrupting effects, the biological and ecological significance of these effects, and their mechanistic bases. The evidence points to natural and synthetic estrogenic hormones (for example, from birth control medications) as responsible for the greatest estrogenic exposure from wastewaters. These hormones occur in wastewater effluents at concentrations, albeit very low (ng/L), that have been shown to elicit possible endocrine mediated effects. Other chemicals found in wastewater (such as phthalates and alkylphenolic compounds) may have weaker estrogenic effects.

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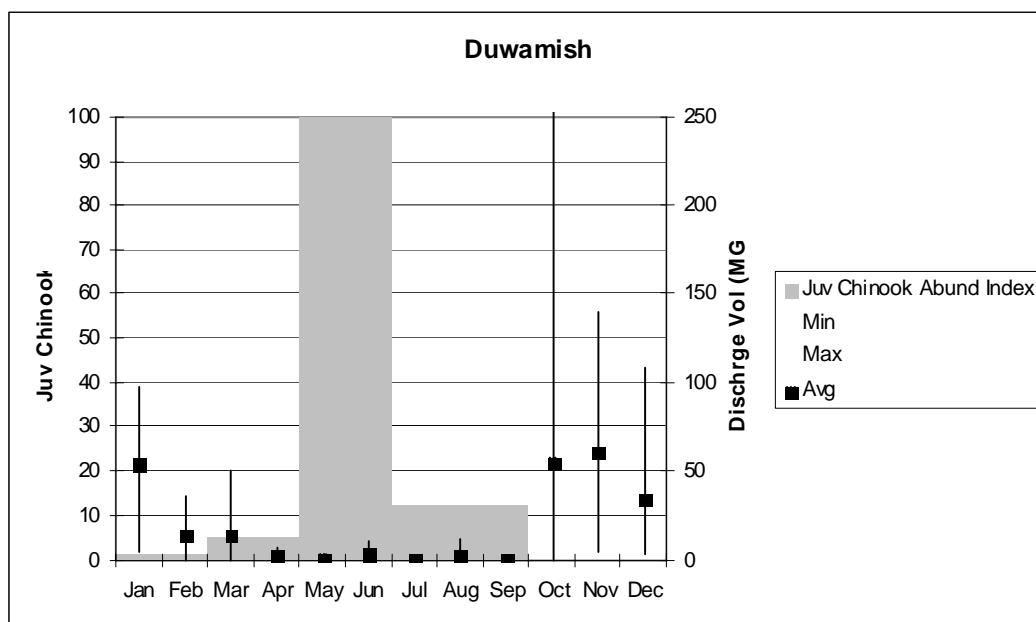
<sup>6</sup> January 2002, *Literature Review of Endocrine Disruptors in Secondary Treated Effluent: Toxicological Effects in Aquatic Organisms*.

There is evidence linking exposure to EDCs with effects on aquatic organisms. EDCs in combined sewage typically are diluted by a 9:1 ratio, and any exposure to aquatic organisms would be expected to be very small and infrequent. The nature and severity of the effects are still being explored. King County will continue to follow the science as it emerges.

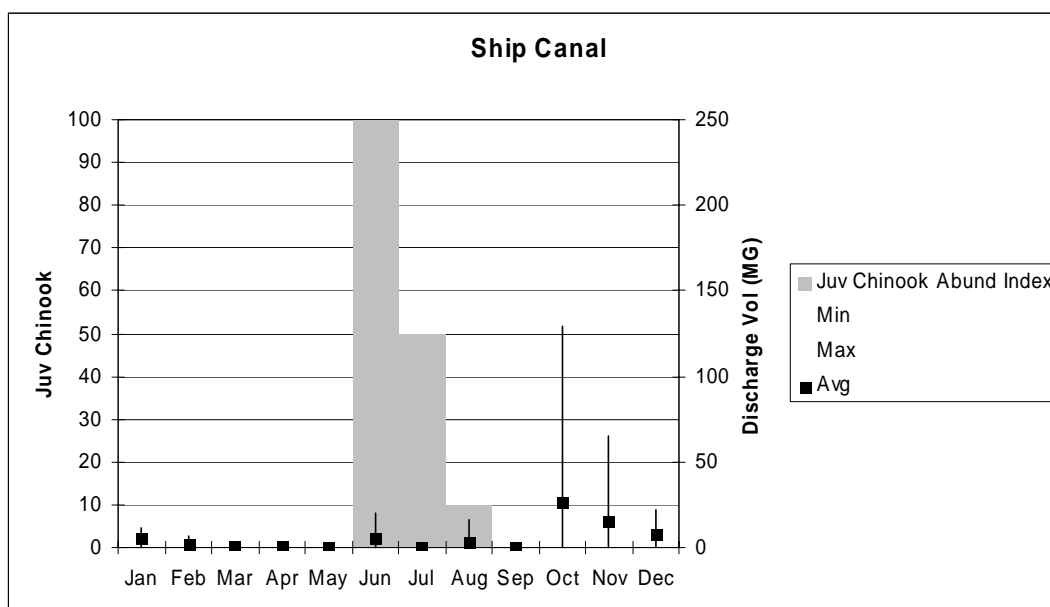
### Possible Exposure of Chinook Salmon to CSOs—King County WTD Studies Conducted for the 2005 CSO Program Review

As part of this CSO program review, an assessment of the presence and abundance of chinook salmon in comparison with average exposure to CSOs was done. The previous 5 years of discharge frequencies and volumes were combined by water body, graphed, and then superimposed on a graph showing the presence and relative abundance of chinook by month. Graphs prepared for the Duwamish River and the Ship Canal are shown in Figure 3 and Figure 4 as examples of the graphs that were prepared. In general, the majority of juvenile chinook salmon are present during periods of the fewest discharges and the smallest volumes; however, every water body had at least one discharge during every month that fish were present.

Juvenile chinook salmon are present in all water bodies for most of the year and have a greater sensitivity and vulnerability than adult chinook to alterations in the nearshore habitats from CSO structures and discharges. However, because the exposure of juveniles to CSOs is infrequent and because chemicals in CSOs are diluted through mixing, it was concluded that CSO discharges present little measurable harm to juvenile Chinook. Additionally, because the essence of an ESA-based evaluation is a comparison between existing and future conditions, implementation of the CSO reduction plan will show a consistent improvement in habitat quality over time.



**Figure 3. Presence of Duwamish River Chinook During CSO Discharge—Monthly Average Volume, 1999-2004**



**Figure 4. Presence of Ship Canal Chinook During CSO Discharge—Monthly Average Volume, 1999-2004**

## Sediment Management Activities—King County WTD and Others, 1999–2005

The RWSP had recognized management of contaminated sediments as important and so had called for the development of a sediment management plan. At the time of the 2000 CSO control plan update, the RWSP sediment management plan (SMP) had been recently completed. It highlighted the growing interest in sediment management as a factor in CSO control planning and the need for more information about CSOs as a current or historical contributor to contamination. The sediment management program was formed to implement the SMP and to implement any new projects developed after the SMP within the broader context of wastewater planning. The program addresses sediment quality issues near CSO discharges and treatment plant outfalls, evaluates and addresses emerging wastewater treatment sediment quality issues, and incorporates sediment quality considerations into comprehensive planning.

### Projects Recommended in the SMP

The SMP assessed areas near seven County CSOs that were listed on the Washington State Contaminated Sites list for their risk, preferred cleanup approach, partnering opportunities, and potential for recontamination after remediation (Table 2). The remediation schedule for these areas, shown in Table 2, is being implemented.

**Table 2. Recommended Projects in the Sediment Management Plan**

Nearby CSO and Water Body	Cleanup Priority	Recommended Cleanup Approach	Partnering Opportunity	Cost (million \$) <sup>a</sup>	Scheduled to be Completed
Duwamish/ Diagonal <sup>b</sup> (Duwamish River)	High	Dredging and capping	King County under direction of EBD RP <sup>c</sup>	8.90 <sup>d</sup>	Completed 2004
King Street (Puget Sound, Elliott Bay)	High	Capping	WSDOT and Seattle	2.60	2008
Hanford (Duwamish River)	Medium/High	Dredging and confined aquatic disposal (CAD)	Port of Seattle	15.49	2007
Lander (Duwamish River)	Medium/High	With Hanford	U.S. Army Corps of Engineers	3.45	2007
Denny A & B <sup>e</sup> (Puget Sound)	Medium	Dredging and capping		2.23	2006
Denny C & D (Puget Sound)	Medium	Capping		0.90	2009
Chelan Ave. (Puget Sound, Elliott Bay)	Low/Medium	Dredging and CAD		2.80	2010
Brandon St. (Duwamish River)	Low	Capping		0.50	2012

a. These costs are given in 2005 dollars (the original estimates, given in 1998 dollars, escalated by 3 percent per year).

b. This project was added after the SMP.

c. These costs were not included in the SMP; it was assumed that they would be paid by the Elliott Bay/Duwamish Restoration Program (EBDRP).

d. EBD RP administers projects funded under a 1990 settlement of litigation by the National Oceanic and Atmospheric Administration (NOAA) for natural resource damages from City of Seattle and King County CSOs and storm drains.

e. This is a City of Seattle storm drain; King County's Hanford No. 1 CSO uses this outfall.

## King County CSOs as Part of Duwamish Superfund Sites

Since completion of the SMP, the Harbor Island Superfund site was extended across the East Waterway of the Duwamish River to include the Port of Seattle's dredging project near the County's Lander and Hanford CSOs. Discussions are occurring with the Port of Seattle and EPA regarding whether King County should participate in the current East Waterway Superfund process and incorporate the remediations near the Hanford and Lander CSO sites into the larger response.

Also since preparation of the SMP, the Lower Duwamish Waterway (LDW) was listed as a federal Superfund site. In December 2000, King County, the Port of Seattle, the City of Seattle, and Boeing entered into an Administrative Order on Consent with EPA and Ecology. Because of their early involvement in the process before the site was listed under Superfund, the agreement gives the County, City, and Port unprecedented access and participation in the initial remedial investigation and feasibility study (RI/FS).

Phase 1 of the RI is completed. The purpose of Phase 1 was to examine existing data on the risks to human health and the environment from sediment-associated chemicals in the LDW, to identify early action remediation candidates, and to focus the scope the Phase 2 investigation.

Although they do not relate directly to CSO control, the Phase 1 studies do represent state-of-the-art knowledge about aspects of environmental and human health related to the Duwamish River where many County CSOs occur.

Phase 2 is currently under way and is estimated to be completed in 2007. Phase 2 will fill the data gaps identified in Phase 1, will assess risks to human health and the environment prior to early action remediations, and will estimate risks, including any risks associated with CSOs, that remain after completion of early remedial actions.

### Results of Phase 1 Remedial Investigation for the Lower Duwamish Waterway

The Phase 1 RI did not identify specific sources of pollution, but did recognize the general categories of historical land use and disposal practices, industrial or municipal releases of wastewater or stormwater, spills or leaks, atmospheric deposition, and waste disposal on land or in landfills. The general impression given in the RI is that chemicals currently found in the sediments result from historical practices over many years.

The Phase 1 RI risk assessment evaluated risks to both the environment and to human health. The environmental risk assessment covered crabs, English sole, juvenile Chinook salmon, bull trout, great blue heron, spotted sandpiper, bald eagle, river otter, and harbor seal. The assessment also examined benthic invertebrate and rooted aquatic plant communities and evaluated studies on effects to juvenile Chinook salmon. While these studies showed increased exposure to chemicals such as PCBs, PAHs, and DDT relative to reference sites, there was not enough evidence to conclude that adverse effects resulted from this exposure. Contaminants of potential concern were identified, preliminary risk estimates for each of the species was done, and recommendations for Phase 2 evaluations were made. For juvenile Chinook salmon, bull trout, and English sole, the following chemicals were estimated to pose low risk: mercury, DDT, and PCBs for salmon; copper for bull trout; and DDT for English sole. The study recommended that Phase 2 further evaluate PCBs, TBTs, PAHs, arsenic, and mercury and collect additional copper and DDT exposure data for these species.<sup>7</sup>

The Phase 1 human health risk assessment identified ways that people could be exposed to chemicals found in LDW sediments, the potential extent of such exposures, and the groupings into exposure scenarios. Direct contact with sediments from commercial netfishing, beach play, and consumption of resident seafood were identified as the three primary exposure scenarios. Forty-three contaminants of potential concern were identified for at least one of these three exposure scenarios. Because of many uncertainties, the human health risks identified in the assessment did not constitute a definitive characterization.

Carcinogenic and noncarcinogenic human health effects were evaluated separately. Estimated lifetime excess cancer risk in the LDW was found to be highest for the seafood consumption scenario, with the cumulative risk for all carcinogenic chemicals estimated at 2 in 1,000 for the tribal resident seafood consumption. The primary contributors were arsenic, carcinogenic PAHs,

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<sup>7</sup> Recommendations for benthic invertebrates, wildlife, and rooted aquatic plants can be found in the Phase 1 RI report.

and PCBs. The cancer risk from netfishing and beach play was much lower but included some risk from dioxins and furans. The assessment identified some potential for other adverse effects associated with seafood consumption, primarily based on arsenic, PCBs, TBT, and mercury.

The risk estimates were high enough to support moving forward with early action remediations, rather than waiting for Phase 2 results. Seven sites were identified for early action remediation. Two of the sites were near King County CSOs: Norfolk and Diagonal/Duwamish. Sediment near the Norfolk site had already been remediated in 1999; remediation of the Diagonal/Duwamish sediment was completed in 2004 by King County, the City of Seattle, and the Elliott Bay/Duwamish Restoration Program (EBDRP).<sup>8</sup> Early actions at sites not associated with CSOs are being implemented by other LDW members.

These RI studies are not complete and conclusions are not firm, but they point in directions that the CSO control program will need to consider in the future. Although fish exposure projections do not warrant alteration of the CSO control plan at this time, emerging information will need to be followed closely. Recent EPA guidance for the Phase 2 human health risk assessment requires the use of fish consumption studies developed by local tribes. The much higher consumption rates will increase the identified risks to human health. Very preliminary Phase 2 results also suggest that current human health sediment quality targets may not be adequately protective and may need to be reviewed. While there is no direct link to CSOs as a cause at this time, the increased attention and concern may influence control and schedule decisions.

### **Post-Remediation Monitoring at the Diagonal/Duwamish and Norfolk Sites**

Fifteen-year follow-up sampling of the Diagonal/Duwamish and Norfolk site remediations was built into the remediation plans for these sites because predictions regarding recontamination could not be made with any confidence. The value of early removal of as much of the contamination by the worst pollutants was considered worth the risk of the occurrence of lesser recontamination.

Five years of monitoring at the Norfolk site has been completed. No recontamination was seen. One sample in the last year showed unexpected contamination, which warrants further examination. So far, the contamination cannot be linked to ongoing CSO or stormwater discharges. The CSO was controlled after the last sampling event.

One year of monitoring at the Diagonal/Duwamish site has been completed. PCB concentrations are approaching the Sediment Quality Standards (SQS) in the cleanup area. However, continued discharges are not expected to significantly increase PCBs in the future because samples taken of sediments in sewer and stormwater pipes that discharge to the area contain comparable levels of PCBs to those found in the cap. PAHs have increased in the cap, but not above SQS when normalized to their organic carbon content. Source control efforts tend to be successful for petroleum products, and several sources have already been controlled. As with PCBs,

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<sup>8</sup> The Elliott Bay/Duwamish Restoration Program administered projects funded under a 1990 settlement of litigation by the National Oceanic and Atmospheric Administration (NOAA) for natural resource damages from Seattle and County CSOs and storm drains.

concentrations of PAHs in source samples are comparable to those in the cap; therefore, cap concentrations are not expected to continue to increase.

Phthalates, however, have increased in the cap significantly since the remediation. Phthalates are believed to come from a variety of sources, perhaps in low levels that add up across many inputs, such as stormwater (via vehicular traffic), wastewater (via everyday products), and air deposition. They are very difficult to control. If the trend cannot be reversed, concentrations in the cap could reach pre-cleanup levels. Phthalates probably accumulate in sediments across the nation. The problem is being highlighted here because Washington State has sediment management standards. The problem will likely not be solved by changes in the CSO control schedule. Phthalate removal efficiency will be included in the pilot tests of promising CSO treatment technologies that will begin in 2006. Considerable discussion is occurring on this topic, and progress will be reported in the 2008 CSO plan update and 2010 CSO program review.

## Climate Change and Sea Level Rise

On October 27, 2005, King County Executive Ron Sims called together experts from across the country in a conference called “The Future Ain’t What it Used to Be—Preparing for Climate Disruption.” The purpose of the conference was to discuss the latest information on global warming and climate change and to begin a conversation on their implications to providers of public services in the Pacific Northwest.

Despite differing opinions on the details and climate models, there is broad scientific consensus that climate change is occurring as a result of human actions, especially the creation of greenhouse gases by burning fossil fuels, and that steps need to be taken to both prepare for the expected affects of climate change and to possibly prevent them from worsening.

Over the twentieth century, the Pacific Northwest has grown warmer and wetter. The average trend in temperature is an increase of 1.4°F since 1950 (an increase of 1.1°F globally), with nearly equal warming in summer and winter. Annual precipitation has also increased nearly everywhere in the region, by 11 percent on average. The greatest increases (about 50 percent) have occurred in northeastern Washington and southwestern Montana.

Regional warming is expected to continue at an increased rate in the twenty-first century. Average increases in warming over the region are projected to reach about 3°F by the 2020s and 5°F by the 2050s. These increases are well outside the natural range of climate in the twentieth century. This rise cannot be turned back because the forces causing it have been set in motion in ocean conditions that respond slowly. Without global intervention, by the 2090s, average summer temperatures are projected to rise by 7.3°F to 8.3°F, while winter temperatures will rise 8.5°F to 10.6°F.

Projections about future general precipitation changes are less certain, ranging from a small decrease (7 percent) to a slightly larger increase (13 percent) through 2050. These changes are within the range of year-to-year variability that has been experienced over the past 100 years in the Pacific Northwest. However, nearly all the climate models show larger seasonal trends of wetter winters with more intense rainfall; projected increases in winter (October–March)

precipitation range up to 20 percent by mid-century. Changes in April–September precipitation are uncertain, while a decrease in June–August precipitation is considered possible.

These factors combined lead to the following general implications:

- Lower-elevation rivers that are fed mostly by rain may see increased wintertime flow.
- Warmer temperatures may result in less winter precipitation that will fall as snow, the snow elevation will rise and there will be less snowpack for later melting and use.
- Spring and snowmelt will occur earlier in the year (already 2 weeks early in parts of the Puget Sound region).
- Rivers that derive some flow from snowmelt will see increased winter flow, earlier peak flow, and reduced summer flow.
- Warmer summers, warmer water temperatures, and lower summer streamflow may result in increased mortality rates for juvenile salmon in streams.

Sea-level rise is another important impact of climate change. Melting of the polar caps, increased river flow, and disruption of climate patterns such as the El Niño will raise sea level and increase the severity of storms and storm surge in parts of the Northwest coast. Low-lying areas are already at risk from projected average sea-level rise and are at even greater risk from average sea-level rise combined with storm waves, accelerated erosion at the base of bluffs and along the coast, and shrinking wetlands.

Compounding sea-level rise resulting from climate change are geological forces related to the uplift or subsidence (sinking) of the land surface as tectonic plates converge (move toward or under one another). Extending from northern California to British Columbia, the Juan de Fuca Plate is being pushed underneath, or subducted by, the North American Plate at a rate of 1.6 to 2 inches per year. In the Pacific Northwest, there are basically two regions of uplifting land, one centered at the mouth of the Strait of Juan de Fuca, rising at 0.1 inch per year, and the other at the mouth of the Columbia River, rising by 0.06 inch per year. On the Washington coast, uplift may offset some of the sea-level rise caused by climate change. The southern portion of Puget Sound, on the other hand, is sinking at up to 0.08 inch per year, or about an inch every 12 years. As a result of this subsidence, risks of sea-level rise are greatest in southern Puget Sound. A rise of 12 to 32 inches over a 75-year period is projected for Puget Sound. (Global sea level is expected to be 19 inches higher by 2100, with a range of 6 to 37 inches).

Potential implications of this information to CSO planning are as follows:

- Increased risk of river flooding and undermining of nearby sewer pipes and facilities
- Increased infiltration into pipes, resulting from higher water tables
- Increased possibility of inflow of river and estuary water into the combined sewer system at outfalls
- Increased inflow into sanitary and combined sewers from impaired drainage of stormwater systems
- Increased pumping to overcome sea-level rise
- Larger pump stations and storage facilities to accommodate increased combined sewer flows resulting from precipitation shifts from snow to rain, with more intense peaks

WTD will monitor developments in the understanding of climate change and sea-level rise. The design of new CSO control facilities or of modifications to existing facilities will consider climate impacts and sea-level change anticipated during the life of the facility. Possible accommodations could include increased sizing, higher facility elevations with respect to nearby water bodies, increased pumping, and enhanced flood and storm surge protections. Decisions as to when to implement these design features will be made based on when it would be most cost-effective to do so while still meeting the need.

## Analyzing Rate Impacts

### Updated RWSP Cost Estimates

**Table 3. RWSP CSO Control Projects**

CSO Location	RWSP Project Description	Dates	RWSP Capital Cost (million, 1998\$)	RWSP Capital Cost (million, 2005\$)
Alaska	0.7 MG storage	2005-2010	\$4.28	(\$5.26, but not needed)
S. Magnolia	1.3 MG storage tank	2005-2010	\$6.76	\$8.31
Murray	0.8 MG storage tank	2005-2010	\$5.06	\$6.23
Barton	Pump Station upgrade	2006-2011	\$9.34	\$11.49
North Beach	Storage/pump station expansion	2006-2011	\$3.94	\$4.84
University/Montlake	7.5 MG storage	2009-2015	\$53.53	\$65.83
Hanford #2	3.3 MG storage/treatment tank	2012-2017	\$27.91	\$34.33
West Point Modifications	Build secondary clarifiers for CSO	2013-2018	\$16.90	\$20.78
Lander	1.5 MG storage, treatment at Hanford	2014-2019	\$26.00	\$31.98
Brandon	0.8 MG storage/treatment	2017-2022	\$13.06	\$16.06
Michigan	2.2 MG storage/treatment tank	2017-2022	\$32.41	\$39.86
Chelan	4 MG storage	2019-2024	\$18.35	\$22.57
Kingdome (Connecticut)	2.8 MG storage/treatment tank	2021-2026	\$31.85	\$39.17
Hanford @ Rainier	0.6 MG storage	2021-2026	\$3.26	\$4.01
King	Conveyance to Connecticut	2021-2026	\$3.15	\$3.87
Terminal 115	0.5 MG storage	2022-2027	\$3.94	\$4.85
West Michigan	Conveyance expansion	2022-2027	\$0.39	\$0.48
8 <sup>th</sup> Ave S	1 MG storage	2022-2027	\$6.87	\$8.45
3 <sup>rd</sup> Ave W	5.5 MG storage	2024-2029	\$28.34	\$34.85
Ballard	1 MG storage (40% King Co.)	2024-2029	\$2.93	\$3.60
11 <sup>th</sup> Ave NW	2 MG storage	2025-2030	\$12.94	\$15.91
CSO Plan Updates	Mandated, but not funded	2000, 2005	\$0	\$5.30 added <sup>1</sup>
<b>Total Program Cost</b>			<b>\$311.21<sup>2, 3</sup></b>	<b>\$382.77</b>

<sup>1</sup> Costs for future program reviews and plan updates are not included.

<sup>2</sup> RWSP CSO budget of \$360 million (98\$) included \$48.77 million for Denny and Henderson, but the projects were accelerated and removed from the RWSP project list

<sup>3</sup> The 2004 RWSP Update reported a total program cost of \$366 million. Corrections identified since would have identified the program cost as \$360 million, both values in 2003\$

## Cost Control—CSO Treatment Technology Review

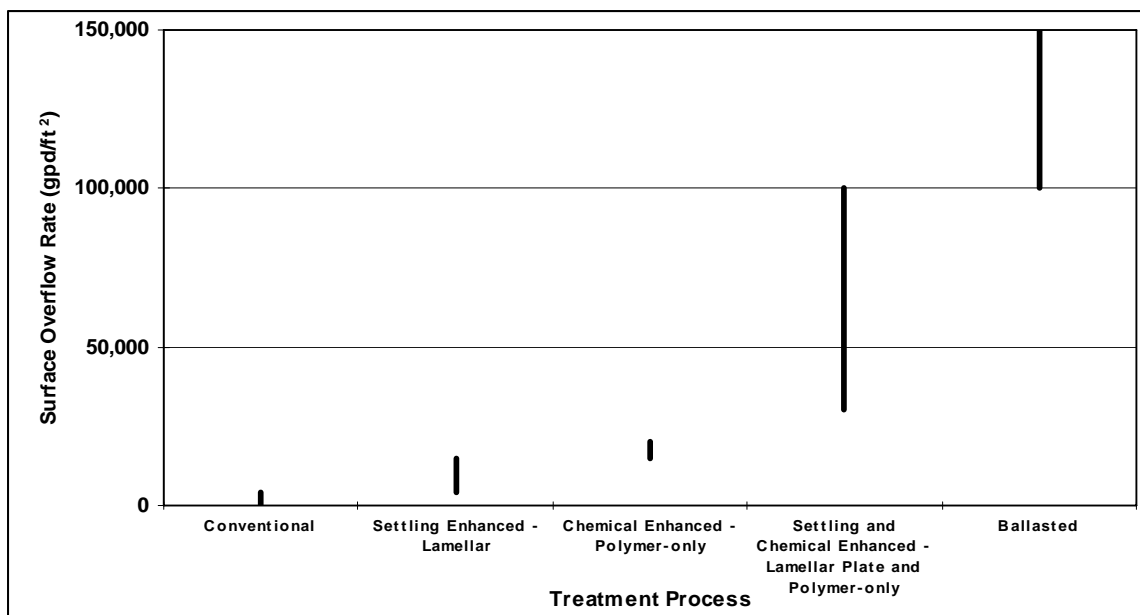
### Solids Treatment Technologies

The following solids removal methods were reviewed and compared to the performance of conventional primary treatment:

- chemically enhanced (polymer-only),
- settling and chemically enhanced (lamellar plate and polymer-only combination), and
- ballasted sedimentation/flocculation.

A key design criteria for solids removal is Surface Overflow Rate (SOR). This is the volume of wastewater treated per square foot of treatment facility (gallons per day per square foot, or gpd/ft<sup>2</sup>). Typically, the higher the SOR, the lower the performance of any solids removal process because the flow passes through the process faster than some of the solids can settle. The SOR relates directly to the footprint or size of a facility. As long as a technology achieves treatment goals, higher SORs will result in smaller size facilities. The size of the facility relates directly to the cost of the facility. Roughly speaking, the higher the SOR, the more flow that can be managed per square foot of facility and per dollar.

While a great amount of theoretical information is available on alternatives to conventional solids removal technologies, actual performance information for CSO applications was quite limited. To compensate, data from stormwater treatment and wet-weather split-flow treatment at secondary plants were also considered. The data sources are summarized in the following pages. The data should be interpreted keeping in mind the differences between stormwater and CSOs—specifically the higher organic material content of CSOs that may be more difficult to remove with primary treatment methods and the higher bacteria counts and the higher proportion of bacteria from human sources. Performance of solids removal technologies taken from the literature reviews is shown in Figure 5. The area below each line in the figure indicates the SORs at which near 100 percent TSS removal is achieved. The top of each line indicates 0 percent TSS removal.



**Figure 5. Relative Performance of Solids Removal Technologies**

In a technology review workshop convened by King County, panel members from consulting firms with experience in CSO treatment rated the different technologies according to criteria considered important to County staff during earlier meetings (Table 4). Conventional primary treatment technologies were rated highest in the more important criteria. Ballasted sedimentation was rated low in those criteria, but rated higher in flexibility and footprint.

**Table 4. Ranked Selection Criteria**

Criteria	Importance
Reliability	Very important
Simplicity of operation	Very important
Treatment performance flexibility	Important
Size/footprint	Important

At the second workshop, the general costs of the technologies were compared. The results, from lowest to highest cost, are listed in Table 5.

**Table 5. Cost of Solids Removal Technologies**

Lowest Cost <span style="float: right;">→ Highest Cost</span>			
High SOR ballasted (SOR = 100,000 gpd/ft²)	conventional primary with polymer addition (SOR = 20,000 gpd/ft²)	conventional primary (SOR = 4,000 gpd/ft²)	low SOR ballasted (SOR = 20,000 gpd/ft²) (as assessed in the 2000 CSO plan update)

## Disinfection Technologies

Four disinfection technologies were compared to conventional disinfection with hypochlorite: chlorine dioxide, bromine, ozone, and ultraviolet (UV). Studies of high-rate chlorination were also reviewed.

Relative effectiveness was rated, in ascending order of effectiveness (Table 6). Even though it ranked lowest in effectiveness, conventional disinfection ranked high. Bromine and UV had mixed results. Conventional disinfection, therefore, remained the technology of choice, with some interest in bromine and UV. Ozone was not recommended for further consideration.

**Table 6. Relative Effectiveness of Disinfection Technologies**

Lowest Effectiveness		Highest Effectiveness
Conventional chlorination with hypochlorite	Bromine disinfection	Chlorine dioxide
		UV
		High-rate chlorination with hypochlorite

Disinfection with chlorine traditionally relies on low doses of chlorine, with long contact times to achieve bacteria kill. Studies of high-rate chlorination showed that contact times on the order of 5 minutes and chlorine doses on the order of 10 mg/L can provide significant reductions in fecal coliform, as long as sufficient mixing energy is provided. Similar to the earlier SOR discussion, contact time relates directly to facility size and cost. Lower contact times can result in smaller facilities and lower cost. Issues to be considered are formation of disinfection byproducts, reaction or bonding (“complexation”) with ammonia, loss of potency while stored (which would be more significant for intermittent CSO treatment than typical wastewater treatment) and material handling safety.

## Assessing Public Opinion—CSO WQA Stakeholder Committee

The stakeholder process for King County’s 1998 *Water Quality Assessment of the Duwamish River and Elliott Bay* (WQA) provided CSO-specific public opinion to the RWSP. The Stakeholder Committee was appointed to provide oversight and input to ensure that the CSO WQA would reflect the values of our diverse community. Members included advocates of environmental, business, tribal, and neighborhood interests, agency representatives, technical specialists, and laypeople. Members of the Stakeholder Committee were as follows:

David Bortz, Washington State Department of Natural Resources  
Elliott Berkihiser, The Boeing Company  
Gerald Brown, Ash Grove Cement  
Patrick Cagney, U.S. Army Corps of Engineers  
Patricia Cirone, EPA Region 10  
B.J. Cummings, Puget Soundkeeper Alliance  
Charles Cunniff, Environmental Coalition of South Seattle  
Allan Davis, Duwamish Valley Neighborhood Preservation Coalition  
Lorna Dove, Georgetown Crime Prevention & Community Council  
Margaret Duncan, Suquamish Tribe  
Kevin Fitzpatrick, Washington State Department of Ecology  
John Glynn, Washington State Department of Ecology  
Bruce Harpham, Rainier Audubon Society  
Patrick Hawkins, King County Regional Water Quality Committee  
Doug Hotchkiss, Port of Seattle  
Larry Kirchner, Seattle-King County Department of Public Health  
Kathy Minsch, Puget Sound Water Quality Action Team  
David Moore, Sierra Club  
Mark Myers, National Marine Fisheries Service  
Tim O’Brian, Duwamish Valley Neighborhood Preservation Coalition  
Sandra O’Neil, Washington State Department of Fish & Wildlife  
Bill Robinson, Trout Unlimited  
Ruth Sechena, University of Washington, Department of Environmental Health  
Gary Shirley, Metropolitan Water Pollution Abatement Advisory Committee  
Chantal Stevens, Muckleshoot Tribe  
Greg Wingard, Waste Action Project